**Historic, Archive Document**

Do not assume content reflects current scientific knowledge, policies, or practices.

1
F76Ge

# Germination of Pine Seed

U. S. Department of Agriculture

Forest Service

UNITED STATES
DEPARTMENT OF AGRICULTURE
LIBRARY

BOOK NUMBER 1
F76Ge

GPO 8—7671

U. S. DEP'T OF AG.
RECEIVED
MAY,
LIBRARY
FOREST SERV

Issued May 16, 1907.

# United States Department of Agriculture,

## FOREST SERVICE.

GIFFORD PINCHOT, Forester.

# GERMINATION OF PINE SEED.

## INTRODUCTION.

The collection of tree seeds and the propagation of seedlings for planting on the National Forests have become part of the work of the Forest Service. To carry this on most successfully, it is necessary that each member of the Service engaged in the work should have a clear idea of the effects of different conditions on the germination of seed. Little has been published in English concerning the vitality, germinative energy, and purity of tree seeds. To secure information on these subjects, tests of pine seed, the results of which are given in this circular, were made by the Forest Service in cooperation with the Seed Laboratory of the Department of Agriculture. Their object was to determine—

(1) The percentage of germination, with special reference to variation between nursery and laboratory tests, and between identical tests under varying temperatures in different localities.

(2) The effect of temperature on the rapidity and on the final percentage of germination.

Though the tests do not suffice for an exhaustive discussion of the subject, they illustrate in general the behavior of pine seed germinating under conditions likely to be met in the Forest Service work.

The laboratory tests and a few of the nursery tests were made at Washington; the majority of the nursery tests, however, were made on the Dismal River National Forest at Halsey, Nebr., and on the San Gabriel National Forest at Pasadena, Cal.

Of the 65 pounds of pine seed used in the tests 44 pounds were collected by members of the Forest Service and 21 pounds were purchased from seed dealers. Only for the Forest Service seed were absolutely reliable data on the age and place of collection obtained.

## SEED GERMINATION.

The percentage of sound seed that trees will bear varies widely, not only with the species but with the individual tree and with the year. No method of test will give the average percentage of germination of all species. Compared with other tree seeds, when tested at the end of their natural rest period, those of pine show a high percentage of germination.

## METHODS AND RAPIDITY OF GERMINATION.

Seeds in general may require from a few days to several years for germination. Pine seed, under normal conditions, will germinate in from one to ten weeks. To conduct nursery practice successfully, definite knowledge must be had of the time required for germination, both in the laboratory and in the seed bed, of all species used. Upon the time of germination largely depends the time of planting in the spring, since a seed requiring eight weeks for germination could be planted much earlier in the season than one requiring but two weeks.

### THE NURSERY TESTS.

The nursery tests at Halsey and Pasadena were made in sandy loam under typical nursery conditions. Those at Washington were made in flat boxes filled with sand and set out of doors. The seeds were planted at Halsey April 17, at Pasadena May 22, and at Washington January 18, 1904. At Halsey and Pasadena water was applied when needed; at Washington none was used. Ninety-four days were required to complete the tests at Halsey, seventy days at Pasadena, and one hundred and forty-five days at Washington. The difference in the time required at Halsey and at Pasadena was probably due to the higher soil temperature at Pasadena at the time of planting. The seeds planted in the sand boxes at Washington probably remained dormant until April 1. On April 13, 1904, the cotyledons of *Pinus ponderosa*, *jeffreyi*, and *murrayana* were breaking ground, and by May 13, 1904, practically all had germinated and appeared above the sand. The germination per cent of six species was far above that obtained at Halsey or Pasadena. Two species, *Pinus edulis* and *jeffreyi*, fell slightly below the percentage secured at those stations. (See Table 1.)

F76Ge



The short time required for germination with favorable temperature conditions may furnish the key for a method of rapid germination of pine seeds. From January to April the seeds were evidently slowly absorbing moisture, and thus, with the advent, in April, of favorable temperature, germination proceeded much more rapidly than if the planting had been deferred until April 1.

TABLE 1.—*Final percentage of germination of pine seeds at the three stations.*

| Species. | Age. | Source. | Germination, out-door tests. | | | Germination, laboratory test at Washington. | |
|---|---|---|---|---|---|---|---|
| | | | Halsey. | Pasadena. | Washington. | Germinate. | Temperature. |
| | *Mos.* | | *Per ct.* | *Per ct.* | *Per ct.* | *Per ct.* | °*F.* |
| Bristlecone (*aristata*) | (?) | Seedsman, Pennsylvania | 48 | 70 | ........ | 82 | 68–95 |
| Knobcone (*attenuata*) | 6 | *California, altitude 4,000 feet. | 52 | 47 | 70 | 52 | 95 |
| Austrian (*austriaca*) | (?) | Seedsman, Kansas | 1 | 6 | ........ | 21 | 55 |
| Foxtail (*balfouriana*) | (?) | Seedsman, Pennsylvania | 69 | 72 | ........ | 90 | 59–86 |
| Coulter (*coulteri*) | 6 | *California | 25 | ........ | 68 | 88 | 68–122 |
| Shore (*contorta*) | (?) | Seedsman, Pennsylvania | 24 | 8 | ........ | 73 | 68–122 |
| Jack (*divaricata*) | (?) | .....do | 60 | 47 | ........ | 95 | 59–95 |
| Do | 6 | *Bemidji, Minn | 58 | 22 | ........ | 75 | 77 |
| Do | 6 | *Escanaba, Mich | 69 | 60 | ........ | 86 | 68–95 |
| Piñon (*edulis*) | 6 | *Santa Fe, N. Mex | 54 | ........ | 45 | 71 | 59–77 |
| Limber (*flexilis*) | (?) | Seedsman, Pennsylvania | 54 | ........ | ........ | 76 | 68 |
| Jeffrey (*jeffreyi*) | 6 | *California, altitude 5,000 feet. | 69 | 86 | 76 | 91 | 59–95 |
| Sugar (*lambertiana*) | 6 | *California, altitude 4,000 feet. | 5 | 2 | 25 | 68 | 68–86 |
| California swamp (*muricata*). | (?) | Seedsman, Pennsylvania | 46 | 37 | ........ | 84 | 59–95 |
| Lodgepole (*murrayana*) | ...... | *Colorado, 10 to 30 years old. | 47 | 45 | 64 | 67 | 59–77 |
| Do | ...... | *Colorado, under 10 years old. | 28 | 27 | ........ | 57 | 59–86 |
| Longleaf (*palustris*) | (?) | Seedsman, New York | 21 | 25 | ........ | 35 | 77–95 |
| Western yellow (*ponderosa*.) | 6 | *California, altitude 5,200 feet. | 36 | 32 | 71 | 68 | 77–95 |
| Do | 18 | *Oregon | 38 | 14 | ........ | 85 | 59–95 |
| Rock (*ponderosa scop.*) | 6 | *Glorietta, N. Mex | 73 | 76 | ........ | 85 | 77 |
| Do | 18 | *Colorado | 66 | 63 | ........ | 71 | 68–86 |
| Do | 18 | *Crawford, Nebr | 55 | 55 | ........ | 64 | 68 |
| Do | 18 | *Rochford, S. Dak | 41 | 59 | ........ | 70 | 68–95 |
| Monterey (*radiata*) | 6 | *California | 76 | 63 | ........ | 79 | 59–95 |
| Do | (?) | Seedsman, Pennsylvania | 55 | 48 | 77 | 59 | 59–95 |
| Red (*resinosa*) | (?) | .....do | 36 | 51 | ........ | 57 | 86 |
| Pitch (*rigida*) | (?) | .....do | 49 | 70 | ........ | 91 | 59–95 |
| White (*strobus*) | 6 | *Minnesota | 36 | 7 | ........ | 65 | 68–95 |
| Do | 6 | *Minnesota (cones washed in kerosene). | 5 | 1 | ........ | 15 | 68–95 |
| Scotch (*sylvestris*) | (?) | Seedsman, Pennsylvania | 13 | 12 | ........ | 31 | 77–95 |
| Loblolly (*tæda*) | (?) | Seedsman, New York | 13 | 3 | ........ | 38 | 68–104 |

* Collected by Forest Service.

A similar test with *Pinus strobus* and *radiata* gave practically the same results. These two species, which differ widely in structure, but which are equally slow to germinate, were kept damp at 50° F. for a period of one hundred days. No sprouts were produced. They were then subjected to a temperature more favorable for germination (from 68° to 95° F.). *Pinus radiata* in seven days and *Pinus strobus* in ten days produced practically the full value (85 to 90 per cent) of the seeds.

This method, which is essentially that of nature, could be used with seeds whose coats are rather hard or impervious, and which, in

consequence, require a comparatively long time to absorb sufficient moisture to start the actual germinative process. In practice the seeds should be sown late in the fall. Germination would then take place some time in April.

An objection to this method would be the danger of injury to the tender seedlings by frost. A freezing temperature while germination was going on would also prove fatal to many of the seeds. Most nut seeds, however, and especially the acorns of the white oak group, practically germinate in the fall.

## THE LABORATORY TESTS.

The results of the laboratory tests at Washington are shown in Table 1, which gives the highest per cent of germination obtained by 15 separate tests, and either the absolute or variable temperature giving that per cent. In general, they show that there is a minimum, optimum, and maximum temperature for the germination of seeds of each species. These vary widely with the different species, as shown by the fact that some Alpine seeds germinate readily at 36° F, while many tropical seeds show no activity when subjected to a temperature of 61° F. The optimum temperature may be defined as that at which the normal seed will germinate best. There will be some variation in the germinative energy of normal seeds, so that the optimum temperature varies somewhat with the individual seed. It follows, then, that with many seeds the optimum temperature is really an alternating temperature within a definite range. In general, the optimum temperature for germination decreases as the latitude and altitude increase.

## METHOD AND PERCENTAGE OF GERMINATION.

Laboratory tests give the percentage of germination to be expected under approximately ideal conditions, such as rarely exist in a nursery or in a prepared seed bed. Nursery tests subject the seeds to conditions which actually prevail in the places where they are to be planted. They give the percentage of seed with sufficient vitality not alone to germinate but also, under normal conditions, to produce a seedling. Laboratory tests give much the higher percentage of germination, though nursery tests give the more reliable and practical results. Table 1 shows that a sample of *Pinus divaricata* germinated 95 per cent in laboratory tests, while in nursery tests seed from the same lot gave but 60 per cent. The nursery tests are the more useful in that they determine how closely the seed must be sown to secure a stated number of seedlings per square or linear foot, and the amount of seed required to sow a definite seed-bed area.

Seed collected by the Forest Service proved, on the whole, of better quality than that purchased from dealers. Seven out of 20 samples of purchased seed possessed such a low degree of vitality that they either failed to germinate, or the percentage obtained was too small to be of any value. Out of the 28 test samples of Service seed but 4 were discarded because of absolute failure or low percentage of germination. In only one instance did a commercial sample surpass a Service sample.

## INFLUENCE OF AGE ON PERCENTAGE OF GERMINATION.

All but four samples of Service seed were collected in the fall and tested the following spring. This prevented extensive comparisons of age with vitality. Of four samples of *Pinus ponderosa scopulorum*, three, which were about 18 months old, showed from 7 to 37 per cent lower germination than the fourth, which was 6 months old.

Seeds of species whose cones are persistent and remain sealed for a number of years, if allowed to remain in the cone retain their vitality for a remarkably long time. A sample of *Pinus murrayana* seed, which had been from twenty to thirty years in the cones, produced approximately 25 per cent more seedlings than seed less than 10 years old, but which had been gathered and extracted the same season in the same locality and stored in the same place.

## GERMINATIVE ENERGY.

The germinative energy of a seed should not be confused with its vitality. A seed has vitality if it is able to sprout; it has germinative energy of a high order if it sprouts quickly, of a low order if it sprouts slowly. Germinative energy, then, relates only to the time element.

Table 2 gives the results of 465 tests made to determine the germinative energy and percentage of germination of 31 samples of seed. In all, 48 samples were tested. Seventeen of these, however, were old and the seed failed to germinate. They were therefore discarded.

The tests were performed in duplicate; most of the results are based on a test of 200 seeds, though a few samples contained but 100 seeds. Test samples of each species were germinated under 15 different temperatures or range of temperatures. To show the germinative energy of each species, the percentage of seeds germinated at the end of four, eight, and fourteen weeks is given. The time required to germinate a reasonably full quota of the different samples varied from ten days to four months.

TABLE 2.—*Percentage of germination of pine seeds, by species and temperatures, at 4, 8, and 14 weeks.*

| Species and period. | Temperature (degrees Fahrenheit). | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 50. | 59. | 68. | 77. | 59–77. | 59–86. | 59–95. | 68–86. | 68–95. | 77–95. | 86. | 95. | 104. | 68–104. | 68–122. |
| Pinus aristata: | *Per ct.* | *Per ct.* | *Per ct.* | *Per ct.* | *Per ct.* | *Per ct.* | *Per ct.* | *Per ct.* | *Per ct.* | *Per ct.* | *Per ct.* | *Per ct.* | *Per ct.* | *Per ct.* | *Per ct.* |
| 4 weeks | 32 | 70 | 75 | 70 | 15 | 79 | 56 | 72 | 82 | 71 | 75 | 76 | 1 | 16 | 2 |
| 8 weeks | 43 | 74 | 75 | 70 | 16 | 79 | 56 | 72 | 82 | 71 | 75 | 76 | 1 | 16 | 2 |
| 14 weeks | 45 | 81 | 75 | 70 | 16 | 79 | 56 | 72 | 82 | 71 | 75 | 76 | 1 | 16 | 2 |
| Pinus attenuata: | | | | | | | | | | | | | | | |
| 4 weeks | 0 | 3 | 16 | 18 | 15 | 17 | 22 | 21 | 17 | 10 | 16 | 15 | 25 | 24 | 28 |
| 8 weeks | 4 | 8 | 18 | 23 | 17 | 21 | 28 | 22 | 24 | 16 | 21 | 33 | 26 | 26 | 36 |
| 14 weeks | 9 | 14 | 21 | 27 | 27 | 26 | 38 | 30 | 46 | 33 | 33 | 52 | 26 | 29 | 38 |
| Pinus austriaca: | | | | | | | | | | | | | | | |
| 4 weeks | 6 | 6 | 5 | 10 | 8 | 6 | 10 | 8 | 9 | 4 | 8 | 2 | 1 | 1 | 4 |
| 8 weeks | 14 | 11 | 10 | 19 | 14 | 9 | 11 | 11 | 12 | 5 | 9 | 2 | 1 | 1 | 4 |
| 14 weeks | 21 | 16 | 10 | 19 | 16 | 9 | 11 | 11 | 12 | 5 | 9 | 2 | 1 | 1 | 4 |
| Pinus balfouriana: | | | | | | | | | | | | | | | |
| 4 weeks | 34 | 80 | 81 | 81 | 84 | 90 | 77 | 84 | 83 | 89 | 78 | 68 | 2 | 33 | 1 |
| 8 weeks | 40 | 82 | 82 | 81 | 84 | 90 | 78 | 84 | 83 | 90 | 78 | 68 | 2 | 33 | 1 |
| 14 weeks | 51 | 83 | 82 | 81 | 84 | 90 | 78 | 84 | 83 | 90 | 78 | 68 | 2 | 33 | 1 |
| Pinus coulteri: | | | | | | | | | | | | | | | |
| 4 weeks | 1 | 0 | 0 | 2 | 0 | 0 | 10 | 1 | 7 | 0 | 1 | 8 | 9 | 18 | 50 |
| 8 weeks | 2 | 0 | 3 | 5 | 1 | 5 | 42 | 3 | 25 | 7 | 4 | 22 | 36 | 24 | 87 |
| 14 weeks | 5 | 8 | 12 | 10 | 20 | 22 | 65 | 21 | 32 | 21 | 13 | 30 | 36 | 24 | 88 |
| Pinus contorta: | | | | | | | | | | | | | | | |
| 4 weeks | 0 | 7 | 7 | 9 | 6 | 12 | 9 | 15 | 12 | 18 | 8 | 15 | 52 | 28 | 59 |
| 8 weeks | 2 | 10 | 15 | 11 | 16 | 26 | 29 | 27 | 37 | 41 | 27 | 42 | 60 | 43 | 71 |
| 14 weeks | 5 | 21 | 24 | 21 | 30 | 42 | 45 | 43 | 60 | 61 | 40 | 52 | 60 | 54 | 73 |
| Pinus divaricata, commercial: | | | | | | | | | | | | | | | |
| 4 weeks | 0 | 58 | 43 | 44 | 75 | 86 | 93 | 40 | 73 | 50 | 46 | 51 | 46 | 24 | 49 |
| 8 weeks | 8 | 64 | 44 | 46 | 81 | 86 | 95 | 76 | 74 | 57 | 49 | 73 | 47 | 24 | 5 |
| 14 weeks | 8 | 67 | 46 | 50 | 83 | 86 | 95 | 82 | 75 | 74 | 58 | 77 | 47 | 24 | 5 |
| Pinus divaricata, from Minnesota: | | | | | | | | | | | | | | | |
| 4 weeks | 2 | 61 | 43 | 74 | 62 | 66 | 68 | 46 | 69 | 55 | 55 | 44 | 25 | 8 | 34 |
| 8 weeks | 14 | 61 | 45 | 74 | 64 | 66 | 68 | 61 | 70 | 56 | 56 | 58 | 25 | 8 | 35 |
| 14 weeks | 17 | 62 | 47 | 75 | 64 | 66 | 68 | 62 | 70 | 58 | 59 | 59 | 25 | 8 | 35 |
| Pinus divaricata, from Michigan: | | | | | | | | | | | | | | | |
| 4 weeks | 1 | 24 | 14 | 16 | 68 | 68 | 72 | 8 | 86 | 26 | 34 | 69 | 67 | 52 | 60 |
| 8 weeks | 9 | 40 | 15 | 28 | 72 | 70 | 77 | 75 | 86 | 52 | 40 | 80 | 75 | 53 | 60 |
| 14 weeks | 12 | 49 | 18 | 50 | 73 | 71 | 78 | 75 | 86 | 64 | 51 | 82 | 75 | 53 | 60 |
| Pinus edulis: | | | | | | | | | | | | | | | |
| 4 weeks | 0 | 40 | 68 | 59 | 64 | 0 | 0 | 69 | 0 | 0 | 43 | 0 | 0 | 0 | 0 |
| 8 weeks | 0 | 51 | 70 | 64 | 71 | 0 | 0 | 70 | 0 | 0 | 60 | 0 | 0 | 0 | 0 |
| 14 weeks | 0 | 65 | 71 | 64 | 71 | 0 | 0 | 70 | 0 | 0 | 64 | 0 | 0 | 0 | 0 |
| Pinus flexilis: | | | | | | | | | | | | | | | |
| 4 weeks | 0 | 22 | 67 | 70 | 43 | 63 | 33 | 64 | 45 | 62 | 61 | 35 | 0 | 0 | 0 |
| 8 weeks | 5 | 29 | 74 | 71 | 70 | 69 | 36 | 65 | 49 | 70 | 62 | 37 | 0 | 0 | 0 |
| 14 weeks | 11 | 40 | 76 | 71 | 73 | 70 | 36 | 65 | 49 | 70 | 62 | 37 | 0 | 0 | 0 |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pinus jeffreyi: | | | | | | | | | | | | | | | |
| 4 weeks | 3 | 0 | 31 | 67 | 13 | 65 | 83 | 75 | 77 | 76 | 78 | 85 | 80 | 61 | 61 |
| 8 weeks | 5 | 7 | 70 | 82 | 48 | 81 | 91 | 83 | 79 | 78 | 85 | 86 | 80 | 71 | 61 |
| 14 weeks | 7 | 49 | 77 | 82 | 82 | 84 | 91 | 86 | 79 | 78 | 85 | 86 | 80 | 73 | 61 |
| Pinus lambertiana: | | | | | | | | | | | | | | | |
| 4 weeks | 1 | 2 | 8 | 6 | 10 | 26 | 32 | 46 | 28 | 23 | 27 | 29 | 26 | 33 | 40 |
| 8 weeks | 31 | 19 | 34 | 40 | 35 | 42 | 50 | 51 | 56 | 43 | 48 | 41 | 26 | 58 | 46 |
| 14 weeks | 63 | 41 | 64 | 60 | 55 | 56 | 60 | 68 | 68 | 48 | 66 | 42 | 26 | 67 | 46 |
| Pinus muricata: | | | | | | | | | | | | | | | |
| 4 weeks | 0 | 1 | 6 | 4 | 13 | 3 | 24 | 5 | 13 | 3 | 4 | 17 | 7 | 31 | 8 |
| 8 weeks | 1 | 2 | 11 | 5 | 31 | 16 | 80 | 25 | 47 | 12 | 8 | 42 | 7 | 41 | 10 |
| 14 weeks | 1 | 18 | 16 | 20 | 48 | 28 | 84 | 48 | 77 | 57 | 29 | 58 | 7 | 43 | 10 |
| Pinus murrayana, age from 10 to 30 years: | | | | | | | | | | | | | | | |
| 4 weeks | 1 | 8 | 31 | 5 | 21 | 46 | 43 | 9 | 58 | 22 | 17 | 31 | 35 | 30 | 26 |
| 8 weeks | 4 | 19 | 34 | 10 | 61 | 58 | 56 | 49 | 63 | 40 | 32 | 58 | 37 | 31 | 29 |
| 14 weeks | 5 | 25 | 41 | 31 | 67 | 63 | 59 | 62 | 64 | 55 | 39 | 65 | 37 | 31 | 29 |
| Pinus murrayana, age under 10 years: | | | | | | | | | | | | | | | |
| 4 weeks | 0 | 5 | 11 | 8 | 16 | 46 | 34 | 7 | 34 | 34 | 13 | 24 | 22 | 20 | 22 |
| 8 weeks | 1 | 13 | 14 | 11 | 27 | 54 | 43 | 21 | 44 | 44 | 28 | 42 | 24 | 21 | 23 |
| 14 weeks | 1 | 20 | 17 | 18 | 36 | 57 | 45 | 23 | 46 | 53 | 33 | 47 | 24 | 21 | 23 |
| Pinus palustris: | | | | | | | | | | | | | | | |
| 4 weeks | 0 | 14 | 10 | 27 | 6 | 25 | 22 | 23 | 24 | 28 | 23 | 14 | 0 | 13 | 0 |
| 8 weeks | 4 | 20 | 10 | 31 | 9 | 31 | 26 | 24 | 27 | 34 | 29 | 20 | 0 | 13 | 0 |
| 14 weeks | 5 | 20 | 10 | 32 | 11 | 33 | 28 | 25 | 28 | 35 | 30 | 22 | 0 | 13 | 0 |
| Pinus ponderosa, from California: | | | | | | | | | | | | | | | |
| 4 weeks | 0 | 0 | 1 | 3 | 0 | 10 | 32 | 22 | 43 | 12 | 4 | 27 | 28 | 28 | 62 |
| 8 weeks | 0 | 1 | 19 | 32 | 25 | 54 | 43 | 54 | 62 | 43 | 12 | 48 | 35 | 38 | 63 |
| 14 weeks | 12 | 23 | 47 | 55 | 45 | 59 | 44 | 59 | 63 | 68 | 37 | 57 | 35 | 42 | 63 |
| Pinus ponderosa scopulorum, from Oregon: | | | | | | | | | | | | | | | |
| 4 weeks | 0 | 0 | 1 | 3 | 0 | 0 | 5 | 5 | 8 | 6 | 4 | 26 | 56 | 15 | 79 |
| 8 weeks | 0 | 0 | 7 | 14 | 7 | 28 | 56 | 21 | 51 | 34 | 15 | 52 | 73 | 42 | 81 |
| 14 weeks | 0 | 3 | 28 | 44 | 36 | 65 | 85 | 62 | 78 | 64 | 35 | 61 | 73 | 62 | 81 |
| Pinus ponderosa scopulorum, from New Mexico: | | | | | | | | | | | | | | | |
| 4 weeks | 0 | 10 | 74 | 84 | 34 | 64 | 62 | 78 | 77 | 80 | 72 | 77 | 52 | 35 | 28 |
| 8 weeks | 0 | 12 | 74 | 85 | 37 | 66 | 75 | 79 | 79 | 80 | 73 | 78 | 54 | 36 | 29 |
| 14 weeks | 0 | 14 | 77 | 85 | 45 | 70 | 77 | 80 | 80 | 80 | 73 | 78 | 54 | 36 | 29 |
| Pinus ponderosa scopulorum, from Colorado: | | | | | | | | | | | | | | | |
| 4 weeks | 0 | 3 | 56 | 61 | 36 | 59 | 58 | 67 | 66 | 56 | 58 | 64 | 49 | 21 | 33 |
| 8 weeks | 1 | 5 | 58 | 63 | 43 | 60 | 61 | 70 | 67 | 57 | 61 | 68 | 53 | 21 | 34 |
| 14 weeks | 1 | 17 | 59 | 63 | 46 | 62 | 63 | 71 | 68 | 58 | 63 | 69 | 53 | 21 | 34 |
| Pinus ponderosa scopulorum, from Nebraska: | | | | | | | | | | | | | | | |
| 4 weeks | 6 | 24 | 63 | 34 | 4 | 34 | 31 | 48 | 57 | 49 | 44 | 40 | 49 | 26 | 27 |
| 8 weeks | 16 | 26 | 63 | 36 | 46 | 36 | 36 | 51 | 59 | 52 | 49 | 49 | 50 | 28 | 27 |
| 14 weeks | 17 | 29 | 64 | 36 | 55 | 40 | 37 | 53 | 60 | 53 | 51 | 50 | 50 | 28 | 27 |
| Pinus ponderosa scopulorum, from South Dakota: | | | | | | | | | | | | | | | |
| 4 weeks | 0 | 8 | 49 | 48 | 33 | 49 | 57 | 46 | 59 | 48 | 42 | 40 | 46 | 34 | 34 |
| 8 weeks | 1 | 10 | 56 | 55 | 53 | 59 | 60 | 54 | 65 | 54 | 59 | 66 | 48 | 35 | 34 |
| 14 weeks | 1 | 25 | 65 | 60 | 61 | 64 | 66 | 59 | 70 | 59 | 68 | 68 | 48 | 35 | 34 |
| Pinus radiata, Forest Service seed: | | | | | | | | | | | | | | | |
| 4 weeks | 0 | 4 | 25 | 33 | 30 | 48 | 57 | 29 | 48 | 38 | 40 | 48 | 6 | 32 | 42 |
| 8 weeks | 4 | 9 | 26 | 37 | 40 | 59 | 66 | 33 | 61 | 52 | 55 | 68 | 6 | 33 | 44 |
| 14 weeks | 18 | 34 | 29 | 43 | 51 | 65 | 79 | 44 | 76 | 71 | 63 | 71 | 6 | 33 | 44 |

TABLE 2.—*Percentage of germination of pine seeds, by species and temperatures, at 4, 8, and 14 weeks*—Continued.

| Species and period. | Temperature (degrees Fahrenheit). | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 50. | 59. | 68. | 77. | 59–77. | 59–86. | 59–95. | 68–86. | 68–95. | 77–95. | 86. | 95. | 104. | 68–104. | 68–122. |
| | *Per ct.* | *Per ct.* | *Per ct.* | *Per ct.* | *Per ct.* | *Per ct.* | *Per ct.* | *Per ct.* | *Per ct.* | *Per ct.* | *Per ct.* | *Per ct.* | *Per ct.* | *Per ct.* | *Per ct.* |
| Pinus radiata, commercial: | | | | | | | | | | | | | | | |
| 4 weeks | 1 | 0 | 9 | 5 | 8 | 27 | 40 | 14 | 28 | 29 | 6 | 34 | 3 | 30 | 16 |
| 8 weeks | 4 | 5 | 14 | 7 | 21 | 42 | 55 | 24 | 45 | 35 | 15 | 44 | 3 | 42 | 17 |
| 14 weeks | 8 | 23 | 23 | 11 | 35 | 55 | 59 | 32 | 57 | 49 | 35 | 47 | 3 | 45 | 17 |
| Pinus resinosa: | | | | | | | | | | | | | | | |
| 4 weeks | 0 | 1 | 23 | 49 | 19 | 40 | 48 | 45 | 54 | 52 | 45 | 21 | 23 | 18 | 36 |
| 8 weeks | 1 | 13 | 52 | 54 | 56 | 54 | 49 | 53 | 54 | 53 | 57 | 30 | 23 | 19 | 36 |
| 14 weeks | 1 | 26 | 57 | 54 | 57 | 54 | 49 | 53 | 54 | 53 | 57 | 30 | 23 | 19 | 36 |
| Pinus rigida: | | | | | | | | | | | | | | | |
| 4 weeks | 0 | 18 | 33 | 32 | 63 | 78 | 86 | 31 | 69 | 37 | 42 | 49 | 51 | 54 | 69 |
| 8 weeks | 1 | 27 | 35 | 52 | 77 | 82 | 90 | 74 | 73 | 46 | 59 | 57 | 61 | 59 | 77 |
| 14 weeks | 3 | 31 | 42 | 70 | 81 | 87 | 91 | 78 | 74 | 59 | 65 | 61 | 61 | 59 | 77 |
| Pinus strobus: | | | | | | | | | | | | | | | |
| 4 weeks | 0 | 3 | 22 | 47 | 15 | 28 | 16 | 36 | 31 | 43 | 39 | 16 | 1 | 21 | 18 |
| 8 weeks | 4 | 11 | 38 | 63 | 28 | 37 | 24 | 48 | 56 | 66 | 52 | 30 | 1 | 24 | 43 |
| 14 weeks | 5 | 20 | 41 | 65 | 33 | 39 | 39 | 52 | 65 | 77 | 61 | 54 | 1 | 27 | 45 |
| Pinus strobus, cones mashed with kerosene to facilitate extraction of seed: | | | | | | | | | | | | | | | |
| 4 weeks | 0 | 1 | 1 | 4 | 2 | 4 | 6 | 5 | 7 | 5 | 4 | 4 | 0 | 5 | 3 |
| 8 weeks | 0 | 2 | 7 | 6 | 5 | 6 | 7 | 10 | 12 | 8 | 6 | 6 | 0 | 5 | 4 |
| 14 weeks | 2 | 2 | 8 | 8 | 6 | 8 | 11 | 12 | 15 | 9 | 8 | 8 | 0 | 5 | 5 |
| Pinus sylvestris: | | | | | | | | | | | | | | | |
| 4 weeks | 1 | 20 | 19 | 15 | 21 | 18 | 20 | 20 | 18 | 19 | 13 | 11 | 10 | 11 | 8 |
| 8 weeks | 17 | 25 | 24 | 19 | 24 | 21 | 24 | 26 | 27 | 27 | 16 | 17 | 10 | 11 | 9 |
| 14 weeks | 27 | 30 | 27 | 25 | 27 | 24 | 29 | 30 | 31 | 31 | 25 | 17 | 10 | 11 | 9 |
| Pinus tæda: | | | | | | | | | | | | | | | |
| 4 weeks | 0 | 0 | 0 | 1 | 0 | 2 | 2 | 0 | 1 | 1 | 0 | 4 | 1 | 3 | 5 |
| 8 weeks | 0 | 0 | 0 | 2 | 2 | 5 | 12 | 1 | 7 | 3 | 4 | 9 | 1 | 15 | 8 |
| 14 weeks | 0 | 0 | 1 | 5 | 4 | 10 | 26 | 4 | 19 | 11 | 9 | 10 | 1 | 38 | 8 |

The germinative energy of seeds is most influenced by moisture and temperature. Moisture is undoubtedly an important factor, but its influence is difficult to determine with accuracy, and in a series of tests it would have to be correlated with the temperature. Since all seeds were subjected to practically the same moisture, it will not be considered independently. Differences in the rapidity of germination will be attributed for the present to the effect of temperature.

Table 2 shows that the higher the temperature the quicker will seeds absorb moisture. This principle is applied when seeds with either exceedingly thick or hard coats are soaked in hot water immediately before planting. Higher temperatures also hasten germination. The results obtained for *Pinus lambertiana* (Table 2) serve as a good illustration of this. The following table shows that a sample subjected to a temperature of 50° F. germinated but 1 per cent of the seed during the first four weeks, though another sample subjected to a temperature of 86° F. germinated 27 per cent during the same period.

*Germination of Pinus lambertiana.*

| Temperature. | Per cent of seeds germinated at the end of— | | |
|---|---|---|---|
| | Four weeks. | Eight weeks. | Fourteen weeks. |
| 50° F. | 1 | 31 | 63 |
| 86° F. | 27 | 48 | 66 |

In this case the percentage of germination gradually equalizes with time, and at the end of fourteen weeks there is a difference of only 3 per cent in favor of the higher temperature. Results obtained from other species, however, show this equalization to be the exception rather than the rule.

### GERMINATIVE ENERGY AS AN INDICATION OF VITALITY.

With seeds of the same species and from the same locality the rapidity of germination is a good index of vitality. Should one sample germinate more rapidly than another, the seedlings of the first will probably be stronger and more vigorous than those of the second. Rapidity of germination loses this significance, however, when the seeds come from different parts of the country.

Table 2 shows that the two samples of *Pinus ponderosa* from the Pacific coast, when compared with the Rocky Mountain samples of the same species, germinated with marked slowness. The Pacific coast seeds were heavier and better filled than those from the Rocky Mountains. A paper by Rafn, of Copenhagen (Mittheilungen der Deutschen Dendrologischen Gesellschaft), states that seeds of *Pinus ponderosa* and of *Pseudotsuga taxifolia*, of good quality, germinate much more slowly

than the poorer Rocky Mountain seeds of the same species. It is self-evident, then, that no established relation exists between the germinative energy of seeds from different localities and the character of the seedlings produced.

It was thought of interest in this connection to ascertain whether or not the statement frequently made and accepted as fact, that seeds from warmer countries require a higher temperature for germination than those from colder climates, applies also to seeds of identical species.

The following table derived from Table 2 will throw some light upon this point:

*Germination of Pinus ponderosa scopulorum.*

| Temperature. | Seed from— | | | |
|---|---|---|---|---|
| | New Mexico. | Colorado. | Nebraska. | South Dakota. |
| 50° F.... | 0 | 1 | 17 | 1 |
| 59° F.... | 14 | 17 | 29 | 25 |
| 68° F.... | 77 | 59 | 64 | 65 |

Those portions of New Mexico and Colorado from which part of the seeds came lie 600 miles south of the Nebraska and South Dakota regions in which the remainder of the seeds were collected. At 50° only 1 of the southern seeds germinated to 18 of the northern; at 59° the proportion was 31 to 54; while at 68° the southern samples surpassed the northern by 7. These tests, then, seem to show that locality affects the minimum temperature of germination of seeds of the same species as well as of seeds in general. This is all the more clearly brought out because the southern samples really possessed a higher percentage of germination under a favorable temperature than did the northern samples.

## MAXIMUM AND MINIMUM TEMPERATURES.

Considerable variation is apparent between the different species in their maximum and minimum temperature of germination. Seeds with high oil content endure the least amount of heat. Doubtless oxidation of these oils sets in early and in sufficient degree to break off the germinative process. *Pinus attenuata, jeffreyi, lambertiana, rigida, ponderosa, divaricata, radiata,* and *strobus* were among those able to germinate at a very high temperature (122° F.). *Pinus aristata, austriaca, balfouriana, lambertiana,* and *sylvestris* germinated quite readily at a temperature of 50° F. The seed of *Pinus lambertiana* is not at all exacting in regard to temperature, germinating almost equally well at any temperature from 50° F to 122° F.

Alternating temperatures were found superior to constant temperatures. Of the 31 samples only 6, or not quite one-fifth, gave the highest per cent of germination when subjected to a constant temperature.

## ESTIMATION OF VITALITY OF SEEDS BY THE CUTTING TEST.

Four hundred seeds of each of the 31 lots tested were cut open to determine the proportion of filled and empty seeds. Table 3 gives the percentage of filled seeds, together with the actual per cent of germination obtained from samples drawn from the same lots.

Table 3.—*Cutting test showing the relation between filled and vital seeds.*

| Species. | Filled seeds. | Germination. | Species. | Filled seeds. | Germination. |
|---|---|---|---|---|---|
| | *Per cent.* | *Per cent.* | | *Per cent.* | *Per cent.* |
| Pinus aristata | 99 | 82 | *Pinus ponderosa | 55 | 68 |
| Pinus attentuata | 98 | 52 | Pinus ponderosa | 93 | 85 |
| Pinus austriaca | 95 | 21 | *Pinus ponderosa scopulorum | 88 | 85 |
| Pinus balfouriana | 97 | 90 | Pinus ponderosa scopulorum | 75 | 71 |
| Pinus contorta | 85 | 73 | Pinus ponderosa scopulorum | 56 | 64 |
| Pinus coulteri | 69 | 88 | Pinus ponderosa scopulorum | 78 | 70 |
| *Pinus divaricata | 97 | 95 | *Pinus radiata | 96 | 79 |
| Pinus divaricata | 97 | 75 | Pinus radiata | 88 | 59 |
| Pinus divaricata | 84 | 86 | Pinus rigida | 87 | 91 |
| Pinus edulis | 97 | 71 | Pinus resinosa | 90 | 57 |
| Pinus flexilis | 67 | 76 | *Pinus strobus | 95 | 65 |
| Pinus jeffreyi | 78 | 91 | Pinus strobus | 93 | 15 |
| Pinus lambertiana | 91 | 68 | Pinus sylvestris | 98 | 31 |
| Pinus muricata | 96 | 84 | Pinus tæda | 73 | 38 |
| *Pinus murrayana | 73 | 67 | | | |
| Pinus murrayana | 53 | 57 | Average | 83. 4 | 67. 4 |
| Pinus palustris | 45 | 35 | | | |

*Where species are duplicated it indicates that the seeds are from different localities.

This method has some value, but not as much as is ordinarily supposed. Skill and care must be used in deciding whether or not a partially filled seed is vital. At best, the estimate is but approximately correct. For 7 samples the per cent of filled seeds is smaller than the actual per cent of germination.

Considering the samples as a whole, 83 per cent of the seeds were perfect, while 67 per cent proved to be vital when an actual germination test was applied. From this it would be safe to expect the germination of about 80 per cent of the filled seed.

## NUMBER OF SEEDS PER POUND.

The average number of seeds of the different species that a pound should contain is difficult to determine. Seeds of the same species collected in widely separated localities, or even at different altitudes in the same locality, may vary greatly in size and weight. Poor seeds naturally weigh less than well-filled seeds. The moisture content doubtless causes a variation of from 2 to 5 per cent in the weights.

Table 4 gives the average number of seeds per pound and pint and the approximate number of linear feet of seed drill covered by each quantity. The calculations are made to secure from 20 to 30 seedlings per running foot. This is not too high for conifers if the seedlings are transplanted when 1 or 2 years old. Since little is known

concerning the requirements and habits of the nut-pine seedlings, the figures for them may be subject to modification.

The number of seeds per pound represents the average of all counts made by the Forest Service. Since the *Pinus ponderosa* seed of the Pacific coast is noticeably larger, a distinction is made between it and the Rocky Mountain form.

TABLE 4.—*Approximate number of pine seeds per pound and pint, and number of linear feet of seed drill covered by each.*

| Species. | Seeds per pound. | Length of drill one pound will cover. | Seeds per pint. | Length of drill one pint will cover. |
|---|---|---|---|---|
| | *Number.* | *Feet.* | *Number.* | *Feet.* |
| Pinus aristata | 21,600 | 360 | 6,200 | 85 |
| Pinus attenuata | 19,000 | 280 | 14,000 | 205 |
| Pinus austriaca | 24,000 | 165 | 15,400 | 110 |
| Pinus balfouriana | 21,800 | 350 | 13,900 | 240 |
| Pinus coulteri | 1,500 | 30 | 1,200 | 24 |
| Pinus divaricata | 115,000 | 660 | 89,000 | 515 |
| Pinus edulis | 2,000 | 30 | 1,100 | 16 |
| Pinus flexilis | 2,700 | 65 | 2,000 | 50 |
| Pinus jeffreyi | 3,000 | 75 | 2,000 | 50 |
| Pinus lambertiana | 2,000 | 50 | 1,200 | 30 |
| Pinus monophylla | 1,450 | 30 | 950 | 20 |
| Pinus ponderosa (Pacific coast) | 9,000 | 140 | 4,000 | 62 |
| Pinus ponderosa | 13,000 | 200 | 5,900 | 90 |
| Pinus radiata | 18,000 | 300 | 12,000 | 200 |
| Pinus resinosa | 60,000 | 900 | 32,000 | 480 |
| Pinus quadrifolia | 1,200 | 25 | 800 | 17 |
| Pinus sabiniana | 525 | 15 | 400 | 11 |
| Pinus torreyana | 600 | 17 | 500 | 14 |

Approved:
JAMES WILSON,
*Secretary of Agriculture.*
WASHINGTON, D. C., *March 15, 1907.*

O

1
F76Ge

Author. U. S.

Title. Germin

Sudw

JUL 1 9 193

FORM 172. LIBRARY, F